Stoichiometry

Relationship between the moles of the reactants and the moles of the products in a chemical equation is indicated by *Coefficients* in the Chemical Equation

C_3H_8 (g) + 5O_2 (g) --> 3CO_2 (g) + 4H_2O (l)

Balanced Equations

Mass Balance

Charge Balance

NH_4^+ (aq) + NaOH (aq) -->
NH_3 (aq) + Na^+ (aq) + H_2O (aq)

Avogadro's Number

6.022137×10^{23} = 1 Mole

1 g = 6.02×10^{23} amu

Amedeo Avogadro (1776-1856) Turin, Italy - Avogadro's hypothesis 1811- equal volumes of gas contain equal numbers of particles

Atomic Weight and Molecular Weight

Grams/Mole

(Daltons)

weight is inaccurate these are actually masses

Conversion of Mass to Moles (Moles are the Currency of Exchange for chemists)

Example:

20 g of Glucose ($C_6H_{12}O_6$ - Mwt =180 g/mol)

20.0 g ÷ 180 g/mol = 0.111 mol

GRAMS → ÷Mwt → MOLES

MOLES → **X Mwt** → GRAMS

Moles to Grams (& volume)

Example:

0.500 moles of Ethanol (C_2H_6O - Mwt =46 g/mol)

0.500 g X 46 g/mol = 23.0 g

D_{EtOH} = 0.90 g/mL

23.0 g ÷ 0.900 g/mL = 20.7 mL EtOH

Problem

How many atoms of Oxygen are present in 4.9 g of H_2SO_4?

4.9 g ÷ 98 g/mol = 0.05 mol H_2SO_4

4 mol of O atoms per H_2SO_4 x 0.05 = 0.20 moles O

6.02×10^{23} atoms/mole X 0.20 moles =
1.2×10^{23}atoms

Predicting Chemical Products

$2CH_4$ (g) + O_2 (g) --> C_2H_6O (l) + H_2O (l)

8.0 g …………………. 11.5 g

÷ 16 g/mol **X 46 g/mol**

0.50 mol x $\frac{1\ C2H6O}{2\ CH4}$ = 0.25mol

Moles are the 'currency of exchange' in chemical processes

Predicting Amounts of Reagents Needed

$2CH_4$ (g) + O_2 (g) --> C_2H_6O (l) + H_2O (l)

8.0 g **8.0 g** **X 32 g/mol**

÷ 16 g/mol

0.50 mol x $\frac{1\ O2}{2\ CH4}$ = 0.25mol

Moles are the 'currency of exchange' in chemical processes

Limiting Reagents

$C_6H_{12}O_6$ (s) + $6O_2$ (g) --> $6CO_2$ (g) + 6 H_2O (g)

18.0 g ÷ 180 g/mole → **0.100 mole**

18.0 g ÷ 32 g/mole → **0.563 mole**

Which is consumed first? Calculate the moles of O_2 needed for the glucose.

0.100 mole Glucose x $\frac{6\ O2}{1\ Glucose}$ = 0.6 mole O_2 needed but only 0.563 available

Oxygen is the limiting Reagent!

Yields of Chemical Reactions

In actual chemical processes the amount of product obtained is rarely as large as the amount predicted by theoretical calculations

Chemical yield = $\frac{\text{Actual yield}}{\text{Theoretical yield}}$

Calculation of a Chemical Yield

CH_3OH (l) + HCl (g) --> CH_3Cl (l) + H_2O (l)

24.0g ÷ 32 g/mole → 0.75 mole

0.75 mole x $\frac{1\ CH3Cl}{1\ CH3OH}$ → 0.75 mole

0.75 mole x 50.5 g/mole → 37.9 g Maximum!

Only 31.3 g of product are obtained. What is the yield?

$$\frac{31.3\ g}{37.9\ g} = 0.826 \xrightarrow{X\ 100\%} 82.6\%$$

Concentration

Amount of substance in a given volume (or mass) of solution

grams/liter

moles/liter, Molarity

m/m and m/v **%** (g/100 g or g/100 ml)

ppt (g/1000 ml)

ppm (g/1,000,000 ml)

ppb (g/1,000,000,000 ml)

Solutions having accurately known concentration

Normal Saline, NaCl 0.85 g/100 ml

Sea Water % composition (mass/mass)

Na	**18,980**	**g/1000 kg (ppm)**
Cl	**10,561**	
Mg	**1,272**	
S	**884**	
Ca	**400**	

Dilution of Solutions

Dilution increases the volume without altering the amount of solute

$$M \times V = \text{moles}$$

initial **final**

$$M_1 \times V_1 = \text{moles} = M_2 \times V_2$$

Calculate the Molarity of con. HCl

Concentrated HCl 35.7% (= 35.7 g/100 g solution)

D_{HCl} = 1.19 g/ml

In 100 mL there are 119 g solution x 0.357 = 42.6 g HCl

$$\frac{42.6 \text{ g HCl}}{35.5 \text{ g/mole}} = 1.20 \text{ moles HCl}$$

$$\frac{1.20 \text{ moles HCl}}{0.100 \text{ L}} = 12.0 \text{ M (moles HCl/L)}$$

What is the concentration of Dilute HCl?

Dilute HCl is prepared by diluting concentrated HCl

V_i = 1L

V_f = 2L

$M_i \times V_i$ = moles HCl = $M_f \times V_f$

$$\frac{M_i \times V_i}{V_f} = \frac{1 \text{ L} \times 12.0 \text{ M}}{2 \text{ L}} = 6.0 \text{ M}$$

Calculate the Density of Con. H_2SO_4

The concentration of H_2SO_4 is 18.0M and it is also 98.0% (m/v)

Therefore: 18 moles in 1 L of solution

18 mole x 98 g/mole = 1764 g H_2SO_4 present in 1 liter of Con. H_2SO_4

But 1764 g is only 98% of the mass so

Mass of 1L of solution must be

=1764 g/0.98 = 1800 g therefore

D = 1800g/1000 mL = 1.8 g/mL

How many moles of H_2O are in 1 L of Con. H_2SO_4?

1 L contains 1800 g of solution but only 1764 g are H_2SO_4

Therefore 1800g-1764g = 36 g H_2O in 1 L

36g H_2O ÷ 18 g/mole = 2.0 mole H_2O in 1 L Con H_2SO_4

Con H_2SO_4 must be 2 M in H_2O!